Environmental Capacity in Industrial Clusters Project

Executive Summary

July 2025

We are the Environment Agency. We protect and improve the environment.

We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

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1. Introduction

Decarbonising industry is essential if the UK is to achieve net zero. It is also a key pathway to opening up growth opportunities through investment in innovation. The Committee on Climate Change's latest advice to Government (2025) states that "we cannot see a route to net zero that does not include Carbon Capture and Storage (CCS)". It also offers huge opportunities for economic growth and regeneration in the UK's industrial heartlands. The Government growth and clean energy missions have committed £21.7 billion into CCS and hydrogen in the East Coast and HyNet (North West) Industrial Clusters.

The Environment Agency (EA) has carried out a four-year proactive review of the environmental capacity needed to sustainably deploy proposed carbon capture and storage (CCS) and hydrogen in key English industrial clusters. The review has evaluated the available evidence and extensively engaged key local and national stakeholders across industry, local authorities and regulatory bodies. It has examined the environmental challenges associated with water availability, water quality, air quality, flood risk and future climate impacts in the Humber, Tees and HyNet industrial clusters.

The EA has drawn together the findings from across each cluster (Section 4), making recommendations which cover potential future policy, additional research and monitoring requirements, and suggested actions for government, industry and regulators (Section 5).

The basis for the findings and recommendations can be found in the main reports that should be read in conjunction with the technical annexes for this project published on GOV.UK.

2. Background

Industrial clusters are economic regions with co-located industries such as power stations, chemical plants, refineries, and manufacturing installations. These are carbon-intensive industries and account for the majority of UK industrial carbon dioxide emissions (CO_2). Located along rivers and estuaries, industrial clusters have associated infrastructure such as ports and investment zones and are well placed to access the UK's world-leading offshore geological storage for captured CO_2. They also co-exist alongside major urban centres, protected ecological sites and sensitive species.

The EA is committed to playing its full part in supporting the Government's growth mission and delivering its ambition for decarbonising industry. In a letter to the Prime Minister (January 2025), Philip Duffy, the Environment Agency's Chief Executive, wrote: *"We can be instrumental in transforming the UK into a centre for the technologies of tomorrow – particularly in areas such as clean energy and the circular economy. Our track record of working with partners on new approaches to carbon capture and storage and hydrogen production demonstrates how we can support this exciting opportunity."*

As the primary environmental regulator in England, the EA already regulates many of the sites within the industrial clusters. The EA is also the environmental regulator for CCS and hydrogen production, playing an important role through planning, permitting and regulation, to enable industry to meet emissions reductions targets whilst protecting the environment.

Whilst the drive for net zero is key, the environment is already under pressure in many places. Low carbon development is likely to place additional stresses on the environment to absorb industrial pollutants and provide the resources required for new industrial processes.

The changing climate will further exacerbate this challenge. Ensuring there is the local capacity for net zero development and environmental capacity for associated impacts is crucial. Making sure challenges are managed strategically and at the right spatial scale is essential.

As a result of this project, the Government's Clean Energy Action Plan 2030 (published in December 2024), made the following commitment: "*We will explore strategic approaches to managing environmental pressures around industrial clusters which engages effectively with the planning and permitting systems. This will help to enable cluster decarbonisation within environmental constraints and address emerging issues prior to projects entering the planning system."*

This commitment was further strengthened when the Government published their Regulators' Action Plan in March 2025, where the EA committed to *"Ensure growth projects consider environmental limits and solutions from the outset by providing technical advice on environmental capacity for growth in industrial clusters to support our approach to spatial planning, commencing with Humberside, Teesside and Merseyside."*

The opportunities for growth within sustainable net zero development in the English industrial clusters are huge. Our recommendations provide advice that will unlock this. Understanding key local capacity challenges will broaden our understanding of the risks and enable the innovation needed to overcome them.

3. Project methodology

The project was phased over four years and covered three English industrial clusters, reviewing environmental capacity as follows:

- Humber
    - for water availability and water quality (Phase 1, 2021-2)
    - air quality and flood risk (Phase 2, 2022-3)
- Teesside
    - water availability and water quality (Phase 2. 2022-3)
    - air quality (Phase 3, 2023-4)
- HyNet (North West)
    - water availability and water quality (Phase 3, 2023-4)
    - air quality (Phase 4, 2024-5)

In the final year of study, the project reviewed current approaches and opportunities for strategic spatial planning to better support deployment of low carbon technology across the same three English clusters. With additional funding from the Regulators' Pioneer Fund, we also piloted a 'proof of concept' digital twin of an industrial cluster, looking at water availability in the Humber.

We engaged with a huge number of local and national stakeholders, as well as EA specialists and leading industry, regulatory and local authority stakeholders. This provided the project with an in-depth view of current knowledge of industry's plans and the specific local environmental capacity issues.

The Appendix (Section 10) includes a case study for each of the three industrial clusters, including specific findings and key messages for each. Evidence on how this project has

already influenced the plans of local government, water companies and industry can be found in the Conclusion (Section 8).

4. Project findings

The main reports, and technical annexes, were published on GOV.UK[1]. They contain detailed information on the findings and recommendations for each cluster that are summarised here:

1. *Strategic Planning*: All industrial clusters have a (non-statutory) 'cluster plan' but these are high-level and mostly focussed on individual low-carbon projects, supply chains and labour markets. They lack sufficient detail for strategic planning and often don't consider properly integrated environmental planning. CCS and hydrogen projects can be covered by a mixture of local land use planning policies and the Nationally Significant Infrastructure Project regime. Local land use planning policies regarding industrial decarbonisation have been seen as an opportunity for regeneration, with good references to individual projects. However, there is little evidence of a strategic approach to how growth might be accommodated in an industrial cluster whilst managing in-combination effects from multiple developments.

2. *Environmental Permitting:* current permitting of low carbon developments takes a first-come, first-served approach. Environmental permits issued to operators effectively set maximum limits for emissions to air and water, above which the regulator considers there would be harm to people or the environment. Most operators will use Best Available Techniques to meet those maximum limits but will not attempt to constrain their emissions beyond that. This means where local environments are already under pressure there are limited options to allow new industry to be deployed as there is no 'headroom' left in the environment. There is no easy, active mechanism to create environmental capacity or to encourage industry to work together to address shared challenges.

3. *Water Availability:* some industrial clusters do not have additional water available to support growth and assume a reliance on short-term plans using the public water supply. New low carbon technology, especially hydrogen production via electrolysis, is water intensive. The project has found that there is insufficient engagement between industry and the water sector to collaborate in finding solutions, and a lack of transparency on their respective sector growth plans. This poses sustainability risks to both the low carbon industries and the water sector.

4. *Water Quality*: many industrial clusters are situated in areas with poor water quality, and contaminated land from legacy industry poses further risks. Specific clusters also have significant issues with nutrient pollution. Wastewater from new low carbon technology is not sufficiently well understood by industry or regulators, and as such potentially delays permitting and operation. There is a lack of data on the cumulative impacts of discharges to surface water quality thresholds. Land remediation offers opportunities for environmental improvement.

[1] Findings can be located on Gov.uk within Environment / Energy infrastructure/Oil, gas and coal / Carbon capture and storage / Research and analysis / Environmental capacity for industrial clusters

5. *Air Quality:* managing local air quality has delivered improvements, including from the ongoing reduction in emissions from industry. However, there is a risk that these improvements could be undermined. New low carbon technology will emit novel emissions to air, and there is a lack of background monitoring data to provide a baseline for new pollutants. Requirements to disclose chemicals likely to be released into the atmosphere from the use of carbon capture solvents is being seen as commercially sensitive by parts of the industry and highlighted as a potential barrier to innovation and developing potentially more efficient carbon capture.

6. *Climate Impacts:* industrial clusters are likely to be highly vulnerable to climate impacts. Located in coastal and estuarine zones, they will be subject to sea level rise and extreme weather. Rivers will become more likely to flood or surface water and groundwater affected by drought. Industrial infrastructure will need to be resilient to climate change to lessen the impact of extreme weather conditions. Industrial clusters need to consider their interdependence on third-party infrastructure (e.g. road, rail and communications).

5. Project recommendations

As a result of our project and its findings, the Environment Agency has developed a set of recommendations aimed at addressing the challenge of environmental capacity for industrial clusters. Our recommendations do not constitute agreed Government policy, though could be relevant to ongoing policy reforms in planning and permitting. They are the result of the evidenced-based review conducted by this project. Neither are they costed or funded. Implementing the recommendations was beyond the scope of the project, but the Environment Agency will work with Government, industry and local partners to further develop solutions and provide advice on future direction.

Planning

Integrate industrial cluster growth into planning reforms: there is an opportunity to set a stronger vision for the environment in sub-regional plans for growth and use current reforms to strengthen the role of integrated planning for industrial clusters. This includes forthcoming Spatial Development Strategies (SDS), local growth plans and the role of either Combined Authorities or new Strategic Planning Authorities, offer the opportunity to set the long-term vision for industrial clusters.

Cluster strategic planning: Growth in industrial clusters will be unlocked with better strategic planning at a ‘cluster-scale’, where the focus goes beyond the individual net zero projects and includes the environmental capacity needed and the associated infrastructure (water, wastewater, waste management) to support them. Putting cluster-focussed plans in place will help to reduce delays by identifying and resolving issues once, rather than leaving them to individual consents. Our project highlights several areas of good practice, including establishing Development Corporations, or using other planning tools, such as Area Action Plans or Supplementary Planning Documents.

Use Strategic Environmental Assessments or Environmental Outcomes Reports at the cluster-scale: Applying environmental assessment (including forthcoming Environmental Outcome Reports) to cluster spatial plans will help identify and assess cumulative impacts of planned and proposed industrial decarbonisation alongside existing environmental challenges. The assessment can inform environmental requirements in the cluster spatial

plan, including the likely scale and need for environmental mitigation. This will help to underpin strategic solutions, potentially including the Nature Restoration Fund.

Develop industrial cluster growth forecasts: Industry needs to develop credible growth forecasts (to 2035) for each cluster for use in spatial planning, industrial and infrastructure strategies and environmental permitting. Whilst Government has set high-level targets, local authorities, regulators and service companies need better forecasts so they can plan associated infrastructure investments and resources.

Permitting

Consider new approaches to permitting: The EA takes a case-by-case approach to permitting on a first-come, first-served basis. In industrial clusters, where environmental capacity is already constrained from existing industry, first-movers of new low carbon technology will quickly absorb any available headroom in the system. Working with Government and industry, the EA could provide technical advice on how permitting could potentially be adapted to help accommodate new growth in already constrained areas, such as the industrial clusters, noting that permitting alone is not the solution and pressures on the environment from non-permitted sources would also need to be addressed.

Review existing permits in industrial clusters: The EA could review existing permits in industrial clusters and explore with Government and industry whether they can be amended to create environmental capacity at a cluster-scale for new developments. The EA has powers under the Industrial Emissions Directive to do this, but they have never been used in this way. The EA could conduct an initial review to understand what this would entail, assess the potential costs to existing businesses and any potential risks.

Review regulatory framework and approach to land remediation: Regeneration and construction, if not planned properly, can lead to severe pollution from brownfield, contaminated sites. However, there can be a significant cost to making land suitable for use and preventing new pollution from legacy contamination. There is an opportunity to review the regulatory framework to ensure that it better supports remediation and takes a proportionate approach that balances the specific risks of remediation and benefits from bringing land back into use.

Model cumulative emissions to air and water: Strategic planning for industrial clusters will require better provision of information and data, and modelling of cumulative emissions to air and water. Industry and cluster partnerships, working with Government and research bodies, could collaborate to ensure better data is available on air and water emissions, and fund modelling of cumulative emissions for each cluster. This should be based on near-term plans, as well as longer-term cluster growth forecasts.

Commission a study on pollution off-setting: Work could be commissioned to undertake a feasibility study that explores opportunities to offset emissions from other sources (e.g. agriculture or transport) both inside and outside industrial clusters, to address the challenge of environmental capacity. This could examine different approaches used internationally, as well as learning from voluntary-carbon and nature markets in the UK.

Water availability

Bring water abstraction licensing into environmental permitting: Defra is planning on bringing water abstraction licensing into environment permitting by 2027, at the earliest. Accelerating this process will provide greater certainty to industry and enable water abstraction to be considered holistically alongside other environmental permitting requirements, especially

wastewater. Providing industry with reassurance that they will continue to have access to water would be a good first step.

Develop cluster-scale water reuse and recycling schemes: Industry and the water sector should collaborate to bring forward cluster-scale water reuse and recycling schemes that allow efficient use of natural resources across and between industrial sites. These schemes should harness the latest innovation and support local economic growth in the environmental infrastructure sector.

Create water demand forecasts: Industry must work with the water sector to provide credible, transparent forecasts for water demand, from both new technology deployments and cumulative development across the cluster. Forecasts must account for future climate impacts on water availability. This will enable the water sector to better engage in industrial growth plans so they can scale their own response to demand, including new investment opportunities.

Water quality

Greater transparency on wastewater impacts: Industry must work with the EA and industry to be more transparent about the potential impacts and composition of wastewater. Industry must develop a better understanding of their waste streams for permitting, to inform the potential impact on rivers and estuaries, options and solutions. This should also include future climate scenarios, such as warmer waters.

Develop an approach for mitigating nutrient pollution from industry: Government, working with its regulators, should consider reviewing the current framework used to manage and mitigate increases in nutrient pollution from industrial development (to water and air). Greater clarity is needed for industry. The new Nature Restoration Fund may provide additional options. Any new approach might consider the role of an enhanced monitoring network, which could inform planning, permitting and appropriate mitigation measures. This also applies to deposited emissions from air, which will also be a source of nutrient pollution.

Air quality

Establish a cluster-scale ambient air monitoring programme: Industry and Government should work together to establish or expand background air quality monitoring programmes in each industrial cluster to provide public reassurance and establish baseline information. Growth in industrial clusters, including deployments of new technology, may alter the local air quality due to potential release of new pollutants (e.g. amine and amine derivatives) and potentially increase others (e.g. nitrogen oxides). There could be a role of UK Research and Innovation (UKRI) programmes to explore viable options and techniques.

Support research and development of innovative alternative non-amine-based carbon capture products: Government, working with UKRI, should provide the support needed to open up the conventional and proprietary carbon capture solvent market to encourage amine alternative products that may be safer to the environment and provide the UK industry a competitive advantage internationally.

Climate impacts

Industrial clusters must be designed for climate resilience: Developers of low carbon developments, including supporting infrastructure (environmental services, ports, pipelines) must determine the level of climate resilience needed and design their infrastructure to achieve it. Industry must ensure development design incorporates future climate impacts

(flood, sea level rise, drought, extreme weather) across all climate change scenarios. New permitting requirements to incorporate climate risk assessments into management systems should encourage this.

Understand interdependencies and cascading failures across industrial clusters: Industrial clusters will become increasingly interdependent, between clusters, different sectors and infrastructure types. Industry must understand how climate impacts and extreme weather will impact those interdependencies – and the risk of cascading failures – to ensure resilience to shocks and operational failures, including environmental incidents. Taking a pathway approach to adaptation planning in clusters – in which a series of staged actions are planned over time - is recommended.

Agreeing common climate impacts data for adaptation planning: Industry and cluster partnerships should work together to understand what climate impacts information they collectively need to help them plan their growth and development. Existing guidance from the EA – the Climate Impacts Tool – is a good starting point, but more detailed climate impacts data will be needed for local and site-specific assessments.

6. Next steps

The success of the Government's growth and clean energy missions in industrial clusters will rely on the Government, the Environment Agency, industry, and local government working together to unlock the environmental capacity for sustainable net zero growth. In addition to the recommendations above, we have set out the following immediate next steps:

1. The Environment Agency will continue to work with industry and local government to provide technical advice ensuring that environmental capacity considerations are embedded into their strategic planning as well as individual project design, where appropriate.

2. Decisions on allocating public funding to new projects in industrial clusters should include assurance that industry has properly considered its potential environmental impacts, they understand the local environmental capacity challenges and have risk-mitigation measures in place to address these.

3. The Environment Agency will support Government in considering different options for permitting and how this might align with planned consultation on reforms to create environmental headroom. Government could also consider how the permitting framework could better contribute to delivering growth in industrial clusters whilst also creating the environmental capacity for industrial low carbon development.

4. Local Planning Authorities and Combined Authorities that are updating local plans or developing new strategies (planning, growth, infrastructure) should ensure that industrial clusters are supported by strong policies that focus on both the proposed net zero developments as well as the associated environmental infrastructure needed to service them.

5. Cluster partnerships should consider updating their 'cluster plans', broadening their scope to include the full infrastructure requirements – including associated environmental infrastructure – for successful cluster growth. Partnerships must ensure that the environmental infrastructure sectors are fully engaged as key stakeholders.

6. Working with Government, the water sector and industry should clarify their respective roles and responsibilities regarding water supply. This could include clearer respective roles of relevant Government departments, water companies, industry and regulators to ensure that industry can be more confident it can access water for new net zero deployments.

7. Industries which are planning on using amine-based solvents for carbon-capture processes must ensure that they can comply with environmental permitting requirements, including environmental assessment levels and requirements for public disclosure. Industry must take a proactive approach to support the development of environmental assessment levels where they do not exist already.

8. UK Research and Innovation should consider how new funding programmes, including the forthcoming Sustainable Industrial Futures Hub, can support sustainable growth in industrial clusters, including better data and research on waste streams, monitoring for new pollutants, and how clusters can adopt circular economy approaches.

9. The Environment Agency could audit the Environmental Management Systems (EMS) of key industrial developments in each cluster to ensure compliance with requirements to have flood risk management plans and climate risk assessments. This would assess the level of preparedness and resilience across regulated industry in industrial clusters.

10. Early learning from Net Zero Teesside on their experiences dealing with land remediation and nutrient pollution should be shared across the different cluster partnerships, so that other projects can incorporate learning into project phasing and design, as well as implementation.

7. Environment Agency offer

The Environment Agency is committed to supporting the Government's clean energy and growth missions. We see investment in environmental capacity as the key to unlocking major infrastructure to enable the country's growth ambitions.

Tackling the effects of climate change by enabling decarbonisation and supporting adaptation to climate impacts is central to our work. We both regulate and work alongside our partners to support ambitions for growth whilst protecting the environment. We have a critical role in supporting and facilitating the delivery of growth ambitions by helping to ensure that the infrastructure and environmental capacity is in place or the protection and enhancement of the environment. We advise around flood risk, protection of land and water quality, water quantity, waste, and biodiversity. We provide advice and expertise that enables climate resilient growth and development that enhances the environment for people, nature, and the economy. We believe that a healthy environment is a vital component of any prospering community, and that any planned developments must be sustainable and not risk causing harm to the environment.

As the primary environmental regulator in England, the Environment Agency regulates many of the installations within the industrial clusters. We regulate emerging CCS and Hydrogen technologies, playing an important role through planning, permitting and regulation, enabling industry to meet emissions targets whilst protecting the environment. We enable effective deployment through our pre-application and permitting service that is supported by local and technical experts. We have already engaged widely locally and nationally to share the

technical findings and advice of this project, taking part in over 200 stakeholder engagements over the duration of the project.

Moving forwards, the Environment Agency will:

- Continue to develop our bespoke Hydrogen and Carbon Capture Utilisation and Storage Programme, supporting industry and local partners by using clear guidance and standards to accelerate the rollout of these projects.

- Accelerate responses to planning applications, bringing performance back within the 21-day target by September 2025, supported by investment in the development of modernised, fit for purpose digital systems and enhancing digital services; and dedicated support for infrastructure related to priority sites contributing to housing and clean energy priorities through its recently established National Infrastructure Team.

- Make our permitting service more efficient and transparent for industry by Introducing priority tracked services for more complex applications, starting with a trial for major infrastructure projects and growth sites.

8. Project conclusion

Reaching net zero is vital and urgent. Government ambitions for net zero need rapid deployment of hydrogen and CCS in industrial clusters. By their nature, industrial clusters are a collective venture dependent on a finite natural resource in locations with limited environmental capacity that is facing further stress under climate change. This challenge needs thorough stakeholder engagement, collaboration between Government, industry, water companies, data and evidence sharing, innovation and flexible regulation.

To meet this challenge the Environmental Capacity in Industrial Clusters project has provided a comprehensive, evidence-based regional overview of the limits of the environment facing industrial decarbonisation in key English clusters. Through a comprehensive programme of local stakeholder engagement, the project has been informed of industry plans for net zero developments and identified the demands that will be placed on environmental capacity and the mitigation needed, now and in the future.

These demands may place additional stresses on natural resources and the capacity of the environment to absorb industrial pollutants. Climate impacts are changing the environmental baseline with warming waters, record temperatures and drought on almost an annual basis.

Whilst this project sets out challenges with a combination of innovation and system-wide, strategic planning. It is possible to sequence strategic net zero developments alongside associated resource needs and habitat mitigations, whilst de-risking public and private investment.

The impact of this project is already being felt. For example, in Humber and Tees following work in 2021-23 (Phases 1-2):

- Project plans are starting to reflect our projected water shortage on the South Humber Bank.

- Phillips 66 Humber Refinery have planned for a reduction in the water available opting to maximise water efficiency in designs of new processes.
- SSE Keadby 3, plan to reduce the water needed for cooling of their carbon capture plant, exploring alternative sources.
- Northumbrian Water have rerun a consultation and re-modelled the maximum available supply to industrial customers.
- Estimates for demand have changed from 25Mld to 190 Mld by 2030. These adjusted figures have been included Northumbrian Water's funding application to Ofwat.
- An EA cumulative impacts study on air quality is underway in Humber and Teesside.
- Detailed water availability assessments are progressing to update the National Framework for Water Resources.

The recommendations and next steps outlined in this executive summary will enable successful delivery of sustainable low carbon and net zero industrial clusters by 2030 and beyond. Action to deliver on net zero commitments means tackling the capacity challenges to get us there. The reward of addressing these challenges is unlocking the huge potential for sustainable growth in the English industrial clusters. A challenge and opportunity that can be shared by all.

9. References and further contact

Products for each Phase of the project are available on GOV.UK: Environmental capacity for industrial clusters - GOV.UK

Phase 1 – Water Availability and Water Quality in Humber industrial cluster
Phase 1 Humber Pathfinder Project final report
Infographic Phase 1
Phase 1 (annex 1) Evidence baseline
Phase 1 (annex 2) Communications and Engagement approach
Phase 1 (annex 3) Summary of Environment Agency stakeholder responses
Phase 1 (annex 4) Summary of industrial stakeholder responses
Phase 1 Humber industrial cluster slide pack

Phase 2 – Air Quality and Flood Risk in Humber, and Water Availability and Water Quality in Teesside industrial cluster
Environmental capacity for industrial clusters: Phase 2 final report
Phase 2 (annex 1) Evidence baseline (Humber)
Phase 2 (annex 2) Summary of stakeholder engagement (Humber)
Phase 2 (annex 3) Evidence baseline (Teesside)
Phase 2 (annex 4) Summary of stakeholder engagement (Teesside)
Phase 2 Humber industrial cluster slide pack
Phase 2 Teesside industrial cluster slide pack
Infographic Phase 2

Phase 3 – Air Quality in Teesside, and Water Availability and Water Quality in HyNet industrial cluster
Phase 3 final report

Phase 3 (annex 1) Teesside Literature review
Phase 3 (annex 2) Teesside Evidence baseline and analysis
Phase 3 (annex 3) Teesside Overview of stakeholders' methods and responses
Phase 3 (annex 4) HyNet Literature review
Phase 3 (annex 5) HyNet Evidence baseline and analysis
Phase 3 (annex 6) HyNet Overview of stakeholders' methods and responses
Phase 3 HyNet Slide Pack
Phase 3 Teesside Slide Pack

Phase 4 – Air Quality in HyNet, and Strategic Environmental Planning review across all 3 clusters, and final executive summary document of findings and strategic recommendations from across all 4 Phases.
Phase 4 final report
Phase 4 (annex 1) HyNet Literature review
Phase 4 (annex 2) HyNet Overview of stakeholders' methods and responses
Phase 4 (annex 3) HyNet Evidence baseline and analysis
Final Executive Summary report
Infographics
Strategic Environmental Planning report
Phase 4 HyNet slide pack
Strategic Spatial Planning slide pack
Executive Summary slide pack

The Environment Agency team can be contacted
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10. Appendix: Industrial Cluster Case Studies

Humber

The Humber region is home to significant industrial and energy assets, including one-third of the UK's oil refineries, with power generation such as the Drax biomass power plant providing 11% of the UK's renewable electricity. High profile projects in the region are planning either carbon capture, hydrogen production, or hydrogen fuel switching, including Triton Power Station, British Steel, Prax Lindsey Oil Refinery, Phillips 66 Humber Refinery and Saltend Chemicals Park.

Industry is spread across a significant portion of the region, including the economic and industrial areas of Grimsby, Hull, Beverley and Scunthorpe. The ports of Hull, Immingham, and Grimsby combined make up the UK's busiest port complex that will provide a significant strategic advantage for future CO_2 storage, with access to 80% of the UK's licensed CO_2 storage capacity. Growth opportunities are abundant in these economic areas as result of plans for a hydrogen supply network, carbon storage and opportunities for hydrogen fuel switching.

The cluster's low carbon technology projects are ambitious, featuring collaborative work such as the Humber Low Carbon Pipelines project, Zero Carbon Humber initiative, and V Net Zero Humber. These focus on developing CO_2 and hydrogen pipelines to enable fuel-switching and CCS. The Northern Endurance Partnership is working on offshore CO_2 storage in the Endurance saline aquifer, while the V Net Zero Humber project is focussing on offshore CO_2 storage via the depleted Viking gas field.

Water resources in the region are under a lot of pressure, caused by a combination of population growth, industrial use and climate change. As a critical resource for industry, water demand in the South Humber is forecast to increase by 160% to more than 181Ml/day by 2050 (WRE 2022). In the North Humber the forecast increase is 12%, to 119Ml/day (WReN 2022). These increases will place major pressures on new industrial growth in the Humber, especially in South Humber.

The Humber region has protected sites for ecology and water quality, classified under the Water Framework Directive (WFD) and Habitats and Birds Directives, which are sensitive to industrial emissions. Sensitive sites around the Lower Humber Estuary are protected by a collection of designations, including a Special Area of Conservation (SAC), a Special Protection Area (SPA) and a Site of Special Scientific Interest (SSSI) under the Habitats Regulations and Ramsar Convention.

The River Humber, Humber Estuary and Rivers Ouse and Trent are already impacted by diffuse pollution from agriculture, storm foul sewer discharges, and industrial emissions. As a result, the upper, middle and lower Humber is considered to have 'moderate' ecological status, indicating that it requires improvement.

Industrial emissions also impact air quality in the region. The contributing factors vary within the Humber, but include traffic, agriculture, import/export shipping and industry. Industrial locations of Scunthorpe, Kingston upon Hull, Immingham and Grimsby have notable background levels of main pollutants associated with industrial activities (sulphur dioxide, oxides of nitrogen, particulate matter).

As a result of the current air quality, Local Authorities declared three Air Quality Management Areas (AQMAs) within the industrial cluster; North Lincolnshire, Kingston upon Hull and North-East Lincolnshire. The North Lincolnshire AQMA includes Scunthorpe Steel

Works and Keadby Power Station, designated for particulate matter PM10 associated with multiple industrial and transport sources. Kingston upon Hull AQMA is designated for Nitrogen Dioxide (NO_2) next to the ports and industry, where the primary source at present is road traffic. In North East Lincolnshire an AQMA designated for Nitrogen Oxides (NOx) in Grimsby was declared in 2010, where industry (power, refineries) producing 5.7% of NOx was the primary source. This AQMA was revoked in May 2024.

These emissions can have a range of possible impacts, affecting human health and the wider environment, with the potential to damage sensitive habitats or species. The Humber Estuary is at an increased risk of impact due to high nutrification, coupled with future unknown background levels of amine solvents used in carbon capture processes.

A changing climate will also impact the Humber. The same risks will also impact other coastal industrial cluster areas. Extremes of weather are likely to increase the risk of flooding with a significant proportion of the cluster already at risk. Areas such as Grimsby, Immingham and Hull are already within or close to the flood plain. Specifically, these locations are within an area that has a 0.5% chance or greater in any one year of flooding from the sea, or a 1% or greater chance each year of flooding from rivers. The Humber 2100+ Partnership of 12 local authorities and the EA is developing a new strategic approach to define how tidal flood risk may be managed into the next century.

The Humber Industrial Cluster Plan (2021) enabled different stakeholders to come together and collaborate on a single vision for the Humber. These partnerships such as the Centre for Assessment for Technical Competence Humber (CATCH) have continued to provide an informal but effective way for local coordination. Planning policy for decarbonisation is strong from local councils, supporting the principles of industrial decarbonisation in the Humber cluster. The Local Authority Local Plans generally include relevant policies that encourage net zero developments. An example of this is found in North Lincolnshire's draft Local Plan that highlights carbon capture and hydrogen infrastructure as encouraged developments.

Despite this, there have been challenges in ensuring effective cross sector join-up between net zero projects and the associated infrastructure projects (e.g. water, wastewater) needed for the region to accommodate growth. Cross-boundary coordination is another challenge, as the Humber Estuary acts as a boundary between different planning authorities. Support for formal collaboration between spatial planners, regulators and industry through industrial cluster groups is needed to support net zero growth in the region.

Our findings from the review of the environmental capacity in the Humber Industrial Cluster are summarised below:

- The Humber environment is already under pressure and the changing climate is making this worse. Existing habitat protection designations, water availability and quality concerns are already challenging environmental permit provision in some locations. Currently, water availability is the key challenge in Humber.

- Industry must engage and collaborate early at a cluster-scale to understand the environment in which they will operate and find innovative solutions to capacity challenges. This will avoid delays to deployment and include reducing the demand for water, using water more efficiently and addressing residual emissions that may impact the environment, to ensure net zero growth is sustainable growth.

- Hydrogen and carbon capture technology have the potential to impact the environment leading to delays in authorisation and deployment. Water availability,

water quality, air quality and flood risk are likely to challenge the deployment of hydrogen and CCS technology in specific industrial clusters.

- New pollutants released from deployment of low carbon technology may lead to worsening local impacts in the Humber. including further habitat degradation. The use of hydrogen as a fuel may lead to an increase in nitrogen oxide emissions and nitrogen/nutrient deposition in the region. Without robust abatement the risk of impacting already affected habitats is high.

Teesside

The Teesside Industrial Cluster aims to be the world's first Net Zero industrial cluster by 2040, with ambitious plans to store up to 10 $MtCO_2$/yr and develop low-carbon hydrogen production, renewable fuels, and circular economy infrastructure, supported by the strategic Teesside Freeport and Tees Works.

The cluster covers key industrial areas including Wilton, North Tees, and Billingham. Teesside serves as a major hub for decarbonisation, with potential for CO_2 imports from South Wales, Solent, and Medway, and hydrogen exports to South Wales, Southampton, and Grangemouth.

Examples of key projects and infrastructure necessary for achieving Net Zero include the Net Zero Teesside (NZT Power), a gas-fired power station with CCS, set to become the first commercial-scale facility of its kind. There are two Bioenergy with Carbon Capture and Storage (BECCS) plants in the cluster – MGT Teesside and Lynemouth Power. Other key power plants in the region include Whitetail Clean Energy Combined Cycle Gas Turbine (CCGT) Teesside.

The Northern Endurance Partnership (NEP) is developing infrastructure to transport CO_2 from industrial emitters in Teesside and Humber to permanent offshore storage, with a capacity of up to 10 $MtCO_2$/yr. Hydrogen infrastructure is expanding through projects including H2Teesside and HyGreen Teesside, with existing hydrogen production, pipeline networks, and storage caverns supporting regional decarbonisation. The cluster is also exploring opportunities for CO_2 import via Tees Valley's deep-water port facilities, enabling international collaboration.

Decarbonisation will change the regions demand for water in the short and medium term. Water availability forecasts in the Tees show that current demand can be met, but forecasts for future long-term availability is uncertain, with supply-demand deficit due to population growth, climate change and increased demand from industry. Current water demand in the region is 60.1ML/day with 296ML/day of demand expected by 2050. Despite a current surplus of water in the Tees it is likely that there will still be water supply challenges as this surplus will be allocated before low carbon technology is deployed later in the decade.

Water Resources North (WreN) envisages the need for future water transfers from Northumbrian Water into Yorkshire to provide public water supply and a secure supply for industrial use. For this to happen, appropriate funding mechanisms need to be in place, suggesting the need for greater collaboration between water companies and industry.

While the large scale inter-regional transfer of water from areas of surplus to areas with deficit could be a solution to longer term water supply issues, there are potential environmental impacts that would need to be considered. Removing water from one resource could have an impact on overall water quality. Water resource is closely linked to

water quality, with abstractions from water bodies (surface and groundwater) potentially influencing water quality in a variety of ways, such as reduced flows (increasing the impact of water discharges) or saline intrusions.

Water quality around the Tees is considered moderate, with rivers affected by diffuse pollution from agriculture, storm and treated sewer discharges and industrial emissions. As a result, some water bodies such as the Lower Tees and Tees Estuary need improvement. The Tees Estuary includes the Teesmouth and Cleveland Coast Special Protection Area (SPA). It is a wetland of European importance. The SPA comprises a wide variety of habitats, including intertidal sand and mudflats, rocky shore, saltmarsh, freshwater marsh, saline lagoons, sand dunes, estuarine and coastal waters on and around the Tees Estuary.

The saltmarsh and mudflat habitats of the Teesmouth and Cleveland Coast SPA are of great importance to a diverse range of bird species. Currently, the SPA is in 'unfavourable condition' for nutrient pressure from excess nitrogen, contributing to an urgent need to prevent harm from increased nutrient levels.

The Teesmouth and Cleveland Coast SPA/Ramsar has been assessed as at risk of eutrophication. This considered assessments of dissolved inorganic nitrogen levels, which are high within the industrial cluster. To bring these levels down would require setting permit limits beyond Best Available Techniques (BAT) for relevant industrial sites and Bran Sands Sewage Treatment Works. This would be very costly and could risk future net zero developments.

The primary environmental challenge is nutrient pressure from discharges to the Tees estuary, and nitrogen deposition from emissions to air at protected designated sites such as the Coatham Sands SSSI. The Teesmouth and Cleveland Coast Special Protection Area (SPA) Site of Special Scientific Interest (SSSI) & Ramsar site surrounds a significant proportion of the industrial cluster and are also sensitive to nutrient deposition.

Habitats most sensitive to nutrients are found downwind of the Teesside industrial cluster and adjacent to the largest industrial redevelopment areas of Teesworks and Wilton International, at South Gare and Coatham Sands SSSI. To manage the nutrient pressures on these habitats in the short term will require a nutrient pollution strategic solution across the Tees.

There is also the risk of pollution from legacy land contamination during the development of industrial clusters, an example of this can be found at Tees Works. Rapid development of net zero projects across the site has the potential to mobilise historical contaminants. Remediation is an opportunity to clean contaminated land prior to development, with careful management and treatment of historical contaminants, to protect and improve surface and groundwater quality.

Air quality monitoring data collected across the region supports the trend of improvement in air quality across the country. This improvement is demonstrated in the annual average nitrogen dioxide (NO_2) concentration in Redcar and Cleveland which has decreased from 24µg/m³ in 2018 to 13.9µg/m³ in 2022.

To further demonstrate improved air quality, no AQMAs have been declared by the councils within the Teesside industrial cluster, reflecting the area's compliance with existing and proposed UK Air Quality Monitoring Station (AQMS) objectives. Ensuring that new net zero deployments don't undermine improvements in air quality or cause new impacts that will require a better understanding of future emissions.

The Tees cluster is primarily located in Redcar & Cleveland and Stockton-on-Tees, within the Tees Valley Combined Authority (TVCA). The TVCA have developed their own spatial planning policy with a Climate Emergency and Net Zero Strategy (2022) that includes an ambition for the Teesside cluster to become the UK's first fully decarbonised industrial cluster by 2040. The plan specifies a Cluster Decarbonisation Plan that collaborates with the 40 largest emitters on measures including carbon capture, fuel switching to hydrogen or electricity, and improved carbon efficiency. Key targets include the deployment of large-scale CCUS by 2030 and 4 GW of hydrogen production by 2030.

Our key findings from the review of environmental capacity in the Teesside Industrial Cluster are summarised below:

- Water quality is likely to challenge deployment in the Tees due to climate change, with stricter limits on pollutants in future discharges likely. There are existing water quality concerns, so permitting additional discharges is likely to be challenging. In the Tees, this will likely include stricter nitrogen nutrient loading limits.

- Development and operation of low carbon technology could help improve the water environment. In the Tees there is an opportunity to reduce river pollution during development. Addressing historic contamination through land remediation can protect and improve surface water and groundwater quality.

- Teesside is currently well placed to provide water for anticipated future demand, but climate change means there is no room for complacency. There is a current surplus to supply for planned deployments in Teesside, although supply for future deployments is uncertain. Future availability of groundwater may be affected due to saline intrusion and groundwater recharge rates. There will be a need for reinvestment in transfer infrastructure, consistent with the Kielder Operating Agreement (regional water transfer system), to meet the demand of expected future deployments without impacting ecology.

- Low carbon technologies have the potential to emit previously unmonitored pollutants which may lead to air quality impacts. Developers need actual baseline monitoring to understand how emissions may impact air quality. Some air quality monitoring is carried out by local authorities such as Redcar and Cleveland Borough Council. Monitoring ammonia and amines in ambient air will help understand the contribution from low carbon technologies and target regulatory control.

- Later deployments of low carbon technology may face significant challenges when combined with impacts from earlier projects are taken into consideration. In Teesside, this could happen at ecological sites such as the Coatham Dunes Site of Special Scientific Interest (SSSI), that already exceeds nutrient nitrogen levels due in part to emissions deposition from existing industry. This will make assessing the impact of new applications harder to determine and may take longer.

HyNet (North West)

The HyNet Industrial Cluster encompasses several key regions with industrial and energy infrastructure, including Cheshire, Merseyside, Greater Manchester, and North West Wales. Additionally, the cluster will cover river catchments such as the Dee and Mersey estuaries, and the redundant oil and gas reservoirs of Liverpool Bay, and the East Irish Sea, which will serve as key storage locations for CO_2.

The cluster will feature large-scale industrial decarbonisation through the deployment of hydrogen production and CCUS. A blue hydrogen production facility by EET Hydrogen at Stanlow, Cheshire, is proposed to supply low-carbon hydrogen, which will be stored in Cheshire's salt caverns by INOVYN. The underground hydrogen transport network is being developed by Cadent and is the first of its kind in the UK. Captured CO_2 from industry is to be transported via pipeline to the Point of Ayr gas terminal and stored in depleted gas fields, such as Hamilton and Lennox in Liverpool Bay by Eni.

The hydrogen produced in the industrial cluster will be utilised across industrial processes and transportation. Over 40 organisations have signed up to decarbonise through HyNet – examples include EET Hydrogen at Stanlow for hydrogen production, Heidelberg Materials at Padeswood Cement Plant and Viridor EFW at Runcorn for carbon capture.

A study of capacity challenges in HyNet identified that water availability in the Lower Mersey south of the Mersey estuary is the most notable area of concern. HyNet assets in this location will be vulnerable to limited or no water available at low flows (Environment Agency 2013).

The Dee Catchment Abstraction Management Strategy indicates that there is no surface water available within the Dee abstraction management catchment for consumptive use, suggesting water trading as an option to get surface water from the River Dee (Natural Resources Wales, 2015).

The Mersey estuary is vulnerable to water quality issues from industrial emissions and wastewater effluents from urban sources. The Mersey estuary has seen improvement in water quality since 1985, due to the 25 year ‘Mersey Basin Campaign’ (Source magazine, 2023) and substantial previous investments by the water company United Utilities (UU). The Mersey estuary is still failing to meet the ‘good’ ecological and chemical objectives set in the most recent River Basin Management Plan (RBMP).

HyNet experiences cumulative nitrogen and sulphur deposition from multiple sources, including industry, transport and agricultural activities. Critical loads for nitrogen deposition are exceeded in some ecological receptors, raising concerns about cumulative environmental impacts. Industrial emissions, particularly sulphur and nitrogen deposition, contribute significantly to air quality concerns. Sensitive ecological sites such as Holcroft Moss Site of Special Scientific Interest (SSSI), part of the Manchester Mosses Special Area of Conservation (SAC), are particularly vulnerable due to in-combination impacts.

HyNet is a key component of the Net Zero North West (NZNW) Cluster Plan, which outlines a strategic pathway for the Northwest of the UK to achieve net-zero industrial emissions by 2040. Local plans in these areas have recognised the importance of major industrial sites, for example, Cheshire West and Chester’s Local Plan (Part One, 2015) designates Stanlow as “a site of national importance” for petrochemicals and related industries, while its Part Two plan further establishes a Stanlow Special Policy Area, safeguarding the refinery and adjacent land for energy and industrial purposes. In the Liverpool City Region, local plans generally zone port and industrial estates (such as Ellesmere Port in Cheshire, or the industrial sites along the Mersey) for ongoing industrial use, which by extension supports new decarbonisation facilities.

Our findings from the review of the environmental capacity in the HyNet Industrial Cluster are summarised below:

- The amount of water available through direct abstraction is likely to reduce due to climate change. Surface and groundwater availability may be a limiting factor for

development around the south-west of the HyNet industrial cluster. Abstractions are at high levels, with pending licence review changes; if developers plan to use non-public water supply from licences that are due to be reviewed, this may have unintended consequences for operations. But there is uncertainty now about which abstractors will be affected.

- Discharges from hydrogen production need further research to understand its cumulative impacts. In HyNet uncertainty exists around wastewater discharges from low carbon technology and the potential thermal, toxicological and ecological impacts around catchments in the region. This is a risk regardless of whether wastewater discharges are direct to surface water or indirect via wastewater treatment works operated by water companies.

- Although not unique to HyNet, hydrogen leakage requires greater monitoring and risk assessment. Stakeholders identified hydrogen leakage as both an industrial and regulatory challenge, with potential climate and safety implications. While hydrogen itself is not a direct greenhouse gas, its interaction with atmospheric methane and ozone contributes to indirect global warming effects. Small-scale leaks from pipelines, storage and industrial processes could also present safety risks and undermine public confidence in hydrogen deployment.

- Carbon capture must address secondary emissions and advance non-amine solvent research. Amine-based carbon capture is currently the dominant technology, but concerns remain over the formation of nitrosamines and nitramines, which require improved monitoring frameworks and regulatory adaptation. This reinforces the need to progress research into alternative, non-amine-based solvents to reduce secondary emissions and improve capture efficiency.

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